Multi-scale, long recording, time-resolved PIV for turbulence statistics and uncertainty reduction in a turbulent jet

A. B. McClenary¹, S. A. Clement²*, P. M. Bardet²

1: Southwest Research Institute, San Antonio, TX, US
2: Department of Mechanical and Aerospace Engineering, The George Washington University, Washington, DC, US

* Correspondent author: simon_clement@gwu.edu

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HIGHLIGHTS

• A new image acquisition system is developed and presented, which allows performing time-resolved PIV at high magnification for long periods of time.
• The use of high magnification imaging allows decreasing significantly the uncertainty of the PIV processing, in addition to resolving all scales of turbulence.
• The energy spectrum is calculated from the time evolution of the velocity fluctuations at one point and compared between different magnifications and recording length.

ABSTRACT

Turbulent flows are made up of a broad range of length and time scales, which are challenging to study experimentally because of the high spatial and temporal resolution required. Particle image velocimetry (PIV) has been traditionally used to resolve turbulent scales spatially. With advances in hardware and processing algorithms, time-resolved PIV now enables to resolve turbulence spectra temporally. The resolution of such spectra, however, requires long time series with large amount of data that typically exceed the memory of modern CMOS cameras. A high speed transfer protocol coupled with CMOS camera is presented, which allows streaming images directly to computer hard drive instead of using cameras internal memory, thus increasing significantly the amount of data acquired while operating at frequencies on the order of the kiloHertz. Such data allow extracting turbulent power spectra from velocity fluctuations time history. Because TR-PIV is a spatio-temporal diagnostic, it is necessary to take into account both scales when designing such experiments. This is illustrated by analyzing the velocity fluctuations power spectra obtained on the centerline of an axisymmetric turbulent jet. The jet Reynolds number is 20,000, which is above the mixing transition. The spectra are obtained temporally using TR-PIV at two spatial resolutions: one at large scale where the interrogation window size is on the order of the Taylor microscale and the other at high spatial resolution, with interrogation windows comparable with Kolmogorov scale. Data show a significant increase in dynamic range with spatial resolution. Another advantage of increasing the magnification is the decrease of the uncertainty of the PIV processing, thanks to the increase in spatial resolution. Finally, the improvement of the spectra with increasing sample size (and hence recording time) is also demonstrated.